

LECTURE 1

The World of Systems

Manual control v/s automatic control

‘CONTROL is the process of causing a system variable to conform to some desired value, a reference value.’

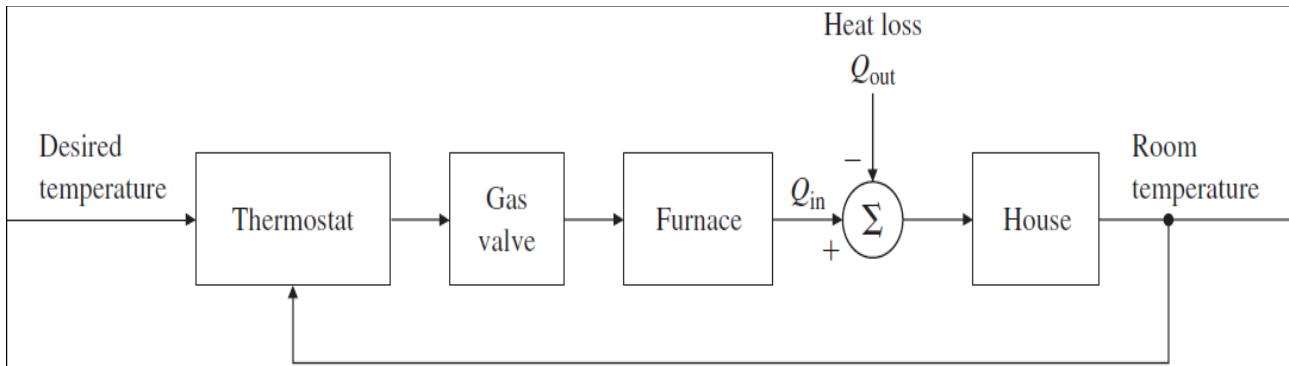
‘FEEDBACK is the process of measuring the controlled variable and using that to influence the value of the controlled variable.’

what is the most complex control system you are aware of?

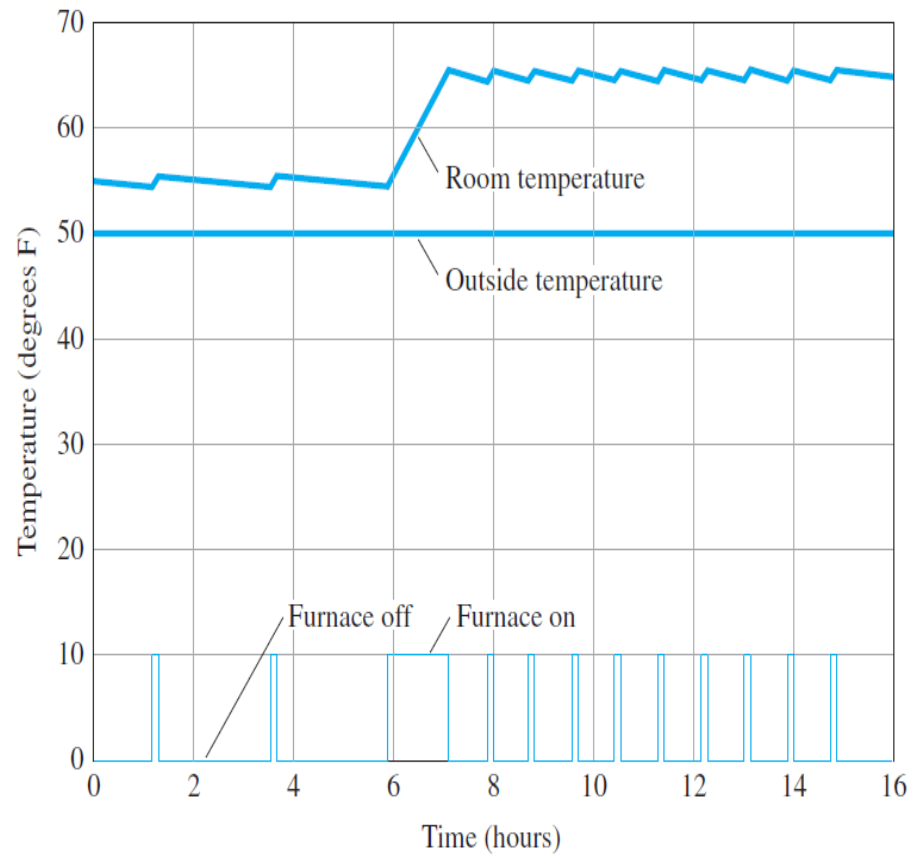
Example of an automatic control system - identify
input, output, actuator, plant/process, sensor
& the BAD GUYS

Section 1.1 – Simple HVAC control for a house
.... What will a component block diagram look like?

- you draw in your note book now



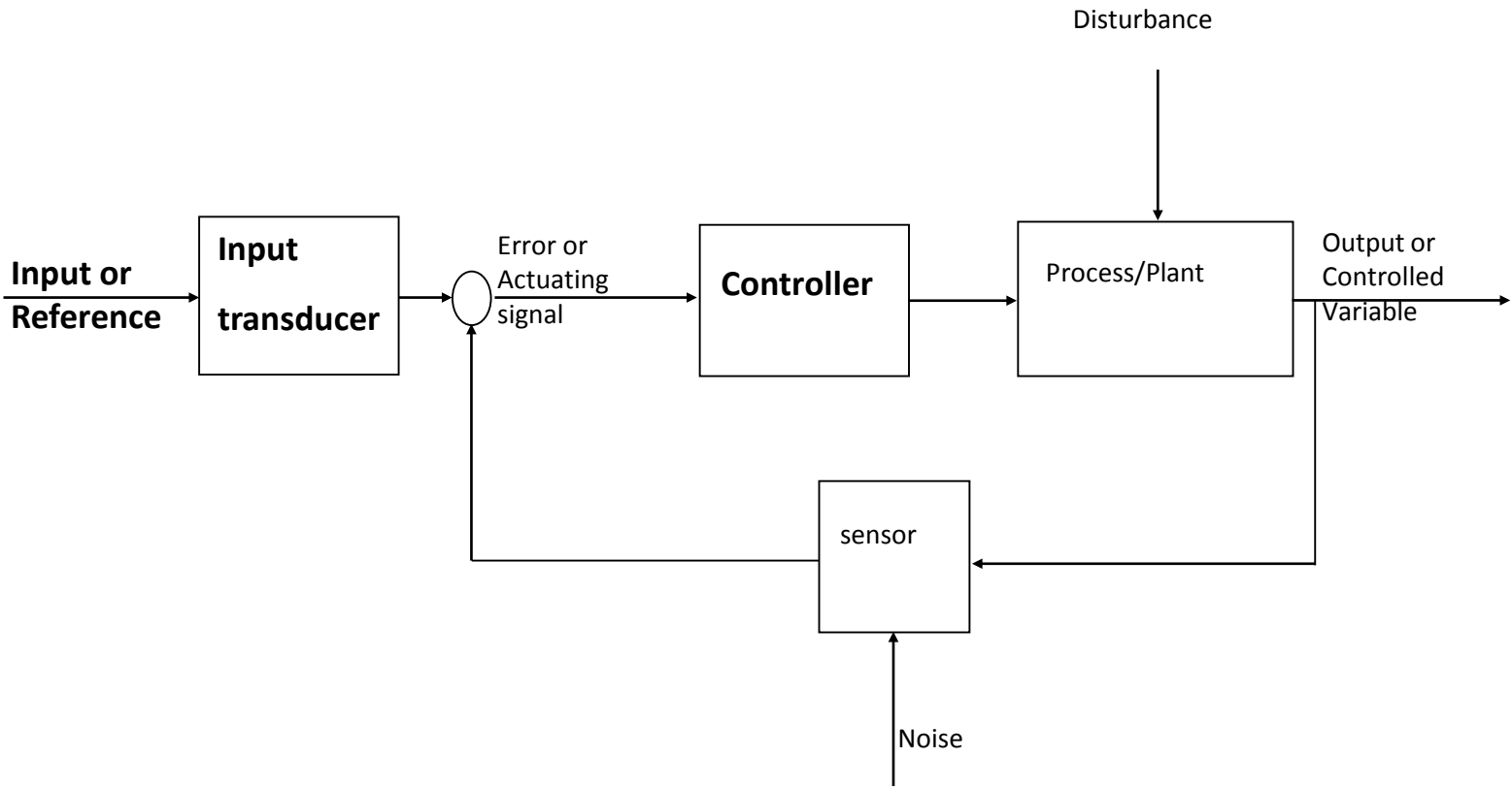
(a)



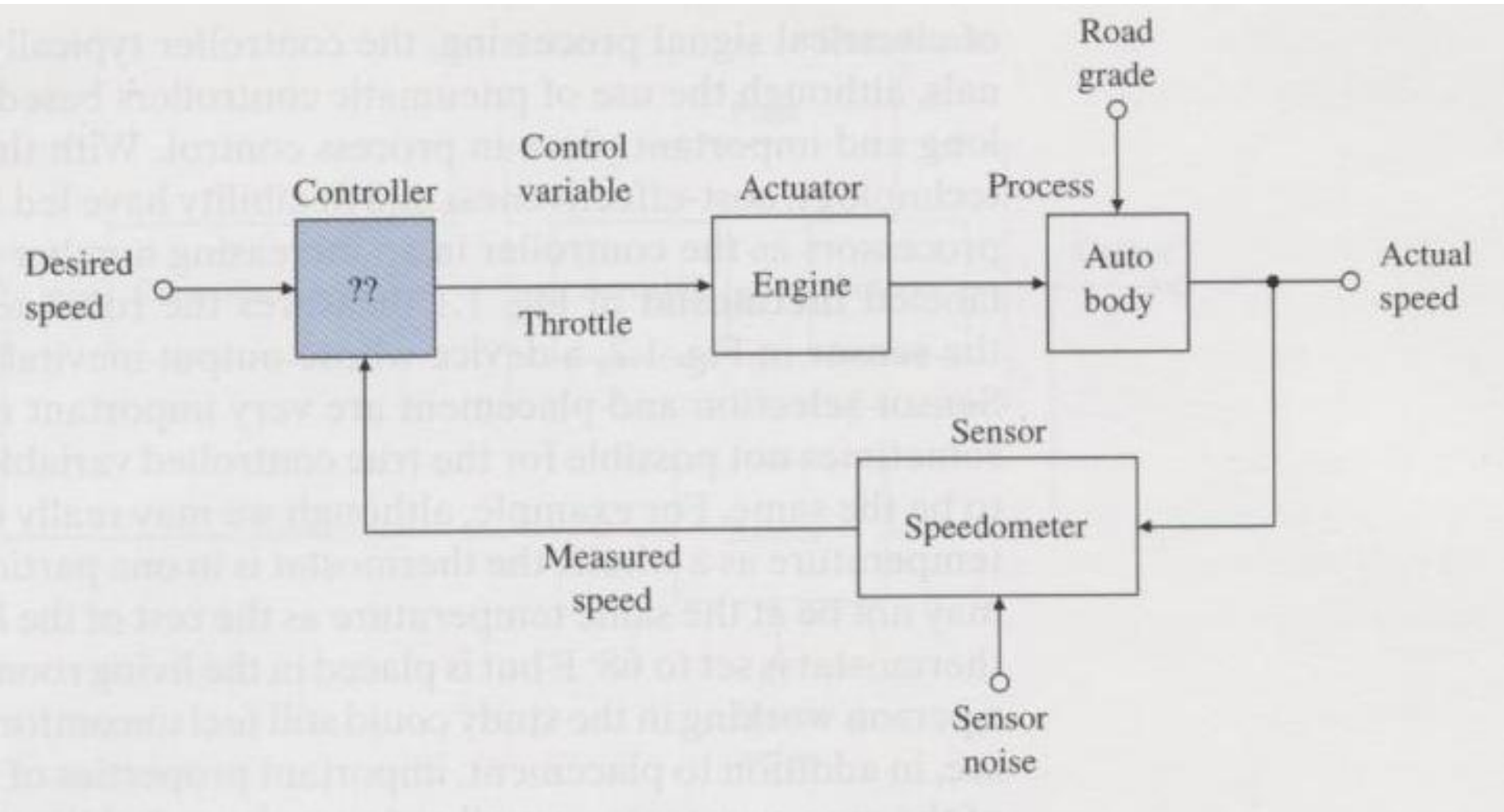
(b)

Section 1.2 – A first analysis of feedback:

First, let's look at a generic block diagram



'Conceptual' block diagram for a cruise controller



'Mathematical' block diagram
what are the assumptions?

Steady state – that is, for a particular throttle angle what is the speed
(what is the other characteristic when you consider buying cars?)

HOW DO WE GET THE DATA FOR MODELING?

If you were to advise one of your technicians about what tests to run to characterize a car, what would be your instructions?

- run the car at 55 mph on level ground first; then check what 1 degree of throttle angle change causes
- run the car at level ground at 55 mph first; then take it on a grade, with the same throttle setting, and see what is the reduction (increase) in speed with 1^o grade (-1^o grade)

1.3 SIMPLE CRUISE CONTROLLER DESIGN

Design a cruise controller for an automobile, considering only steady state characteristics.

Part A: Modeling

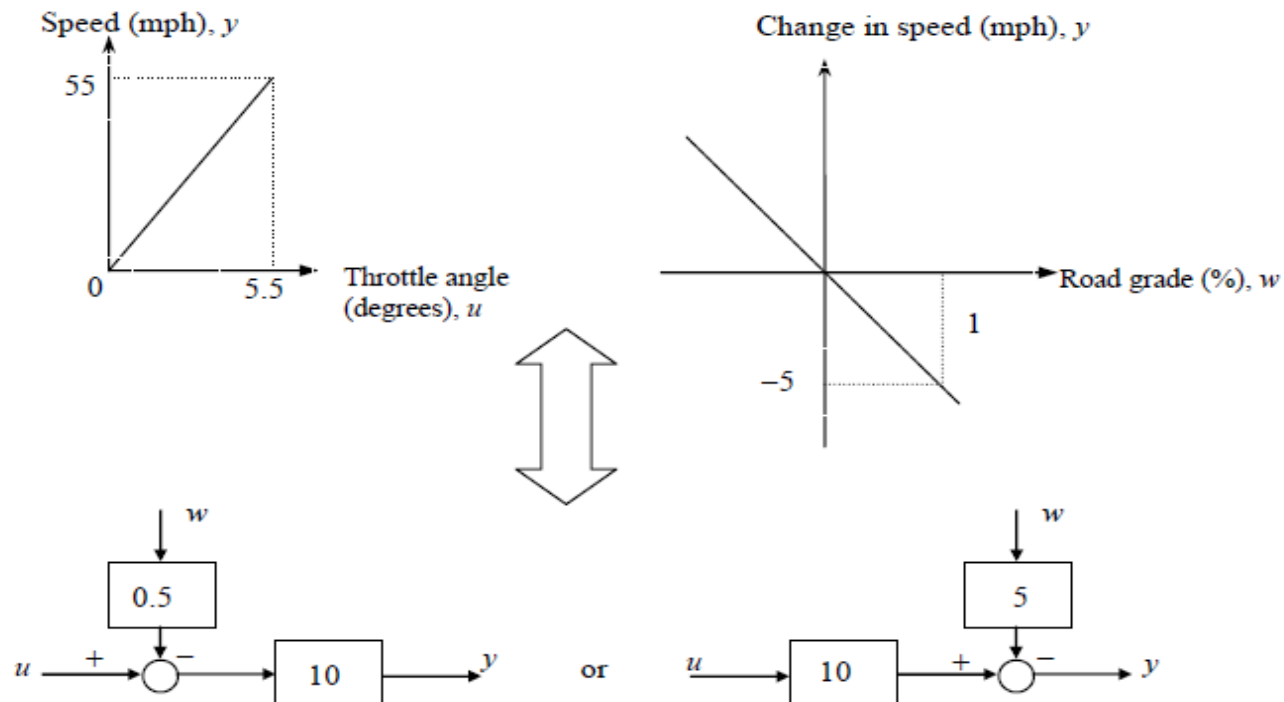
Problem: An engineer performed the following tests to determine the dynamic features of an automobile, for modeling the steady state characteristics, to be used in a simple cruise controller design:

- (i) he measured the speed of the vehicle on level road around 55 mph and found that a 1 degree change in throttle angle (control variable) caused a 10 mph change in speed.
- (ii) he found that when the grade changed by 1%, the speed changed by 5 mph.

Given these experimental observations, develop an automobile model, for control purposes.

Solution:

Assuming linear variation, and that 0° throttle angle results in zero speed, you can get the speed v/s throttle angle graph shown below.



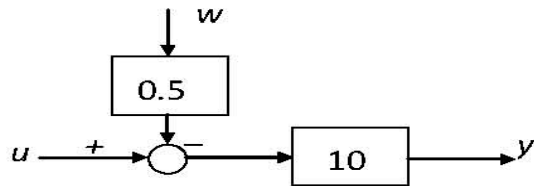
So, the model developed from experimental testing is as follows:

$$y = 10u - 5w,$$

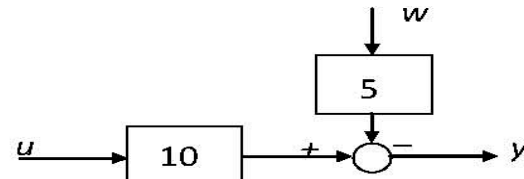
where y is the speed (mph), u is the throttle angle (degrees), and w is the road grade (%).

Part B: Open Loop vs. Closed Loop Control

Problem: Get y as close to r as possible

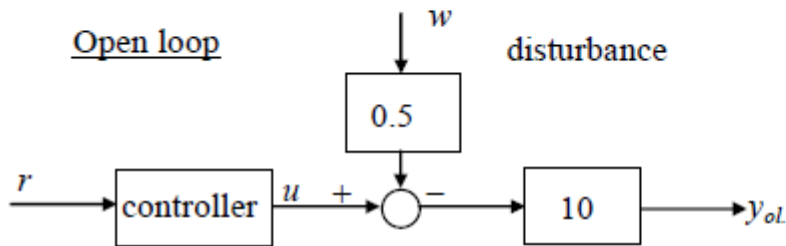


or



Solution:

Add a controller (decision-maker) $\begin{cases} \text{open loop} \\ \text{closed loop} \end{cases}$



How to decide on the “controller”? i.e., what number to put in that block?

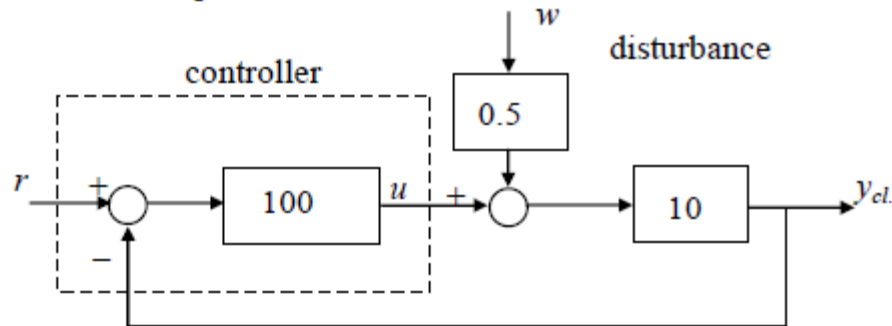
Note: Have no idea what “w” will be. It can be +ve or -ve. DISTURBANCE!
So ignore it, i.e. set $w = 0$.

$$\Rightarrow \text{controller} = \frac{1}{10} \text{ to get } y = r$$

With this controller check for error with disturbance

$$y_{ol} = r - 5w$$

Closed loop



$$y_{cl} = 0.999r - 0.005w$$

Effect of Disturbance

r	w	OL		CL	
		y _{ol}	%error	y _{cl}	%error
55	0	55	0	54.945	0.1%
55	1	50	10%	54.94	0.1%
55	2	45	20%	⋮	⋮
⋮	⋮	⋮	⋮	⋮	⋮
55	10	5	91%	54.9	0.2%

Effect of Parameter Variation

r	gain	OL		CL	
		y _{ol}	%error	y _{cl}	%error
55	10	55	0	54.945	0.1%
55	9	49.5	10%	54.94	0.1%
55	8	44	20%	⋮	⋮
⋮	⋮	⋮	⋮	⋮	⋮
55	1	5.5	91%	54.9	0.2%

*How large can the controller gain be?

...“The issue of how to get the gain as large as possible to reduce the errors without making the system become unstable and squeal is what much of feedback control design all about”

1.1 CONTROL - A Historical Perspective

Era	Year	Individual	Contribution
Ancient Control	300 BC	Ktesibios	Water Clock
	250 BC	Philon	Oil Lamp
Early control	1624	Cornelius Drebbel	Incubator
	1728	James Watt	Flyball Governor
	1846	William Siemens	Integral Control Flyball Governor
	1868	James Maxwell	Governor Analysis with Stability
	1877	Edward Routh	Routh Stability Criteria
	1890	Lyapunov	Stability of Nonlinear Differential Equations
	1895	Adolf Hurwitz	Stability Criteria
Pre-Classical Control	1910	Elmer Sperry	Gyroscope and Autopilot
	1922	Nicholas Minorsky	PID Control Law
	1927	Bush	Differential Analyzer
	1930	Harold Black	Negative Feedback Amplifier
	1932	Harry Nyquist	Nyquist Stability Criterion
Classical Control	1938	Hendric Bode	Frequency Domain Analysis
	1940	Westinghouse	Introducing Laplace Transform into Controls
	1942	J.G. Zeigler and N. B. Nichols	Zeigler-Nichols Tuning Rules
	1942	Wiener	Optimal Filter Design
	1948	Walter Evans	Evans Root Locus
Modern Control	1957	Richard Bellman	Dynamic Programming
	1958		Recognition of Lyapunov Stability
	1960	R.E. Kalman	Optimal Estimation
	1969	Hoff	Microprocessor